USDA Natural Resources Conservation Service
National Employee Development Center

Module 115

Streamflow

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Engineering Hydrology Training Series

Module 115—Streamflow

National Employee Development Center
Natural Resources Conservation Service
United States Department of Agriculture
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Preface

This module consists of a study guide presentation that provides an introduction to streamflow.

Proceed through this module at your own pace. Be sure you completely understand each section before moving on. If you have questions or need help, please request assistance from your supervisor. If your supervisor cannot clear up the problem, he/she will contact the state-appointed resource person. The resource person is familiar with the material and should be able to answer any questions you may have.

Acknowledgment

The design and development of this training module is the result of a concerted effort by practicing engineers in the Natural Resources Conservation Service. The contributions from many technical and procedural reviews have helped make this module one that will provide needed knowledge of hydrology and hydraulics to NRCS employees.

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Module Description

Objectives

Upon completion of this module, the participant will able to:

- Identify NRCS needs for streamflow data.
- List the data sources for streamflow.
- Describe streamflow variability.
- Distinguish between riparian and prior appropriation water rights.
- Identify common state agencies responsible for water laws.

Prerequisites

Module 101—Introduction to Hydrology and
Module 102—Precipitation

References

National Engineering Handbook, Section 4, Hydrology, Chapter 5.

National Handbook of Recommended Methods for Water Data Acquisition, Chapter 1, "Surface Water" Office of Water Data Coordination, Geological Survey, U.S. Department of Interior, Reston, VA 22092.

Duration

Participant should take as long as necessary to complete this module. Training time for the module is approximately one hour.

Eligibility

This module is intended for all NRCS employees who use streamflow data.

Method of Completion

This method is self-study, but states should select a resource person to answer any questions that the participant's supervisor cannot handle.

Overview

This module presents streamflow data sources, streamflow variability, and water rights doctrines laws.

Module 115—Streamflow

Introduction

Streamflow data includes flow rates, volumes of flow, time of flow, and hydrograph shape. The U.S. Geological Survey is responsible for collecting, storing, and retrieving streamflow data in the United States. Either actual data or relationships based on actual data are used in all NRCS programs.

This module deals with the sources of streamflow data and also some considerations to keep in mind while working with streamflow data.

Streamflow Data

Within NRCS, the three general needs for streamflow data are:

- The National Water and Climate Center in Portland, Oregon uses streamflow data in many of its forecasting procedures.
- Water rights for irrigation and municipal use are heavily dependent on streamflow data. The design and operation of many irrigation systems in the western states are dependent on knowing how much water is flowing in a particular stream. The design and operation of municipal and rural water supplier and recreation reservoirs are based on streamflow measurements.
- Engineers need to know streamflow data when designing water resource projects, such as rock riprap and stream channel improvement jobs. Streamflow data are often compared with runoff estimates based on rainfall, soils, and land use. Streamflow data is used in preparation of environmental assessment for water resource project documents.

Sources of Data

The water supply papers prepared by the U.S. Geological Survey (USGS) are the most common source of streamflow data used by NRCS. Most NRCS state offices keep a complete file of water supply papers for their jurisdiction. These papers are usually maintained within the state engineer's office. In some states, the snow survey data collection officer or water supply specialist may be maintaining these files. An example of a standard water supply paper is given in figure 1.

10011500 BEAR RIVER NEAR UTAH-WYOMING STATE LINE

LOCATION.-Lat 40°57'55", long 110°51'10", in. SE1/4 NW1/4 SE1/4 sec 30, T. 3 N., R. 10 E, Summit County, Utah Hydrologic Unit 16010101, on left bank 400 ft downstream from West Fork and 2.8 mi upstream from Utah-Wyoming State line.

DRAINAGE AREA.—172 mi2

PERIOD OF RECORD—July 1942 to current year.

REVISED RECORDS.—WRD UT-74-1: Drainage area.

GAGE.—Water-stage recorder. Elevation of gage is 7,965 ft. above sea level, from river-profile map. Prior to Oct. 1, 1986 at datum 3.0 ft. lower.

REMARKS KS.—Records good except for estimated daily discharges, which are poor. Flow regulated slightly by Whitney Reservoir, total capacity, 4,700 acre-ft since 1966. Three diversions above station for irrigation of about 265 acres above and 2,600 acres below station.

EXTREMES FOR PERIOD OF RECORD,—Maximum discharge, 3,320 ft. 3/s June 6, 1986, gage height, 4.05 ft; maximum gage height, 4.28 ft. June 19, 1983, datum then in use; minimum, 6.8 ft 3/s Apr. 12, 1984, result of upstream ice jam.

EXTREMES FOR CURRENT YEAR.—Peak discharges greater than base discharge of 1,100 ft3/s and maximum (*):

Date	Time	Discharge (ft3/s)	Gage height (ft)	Date	Time	Discharge (ft3/s)	Gage height (ft)
May 26	2400	*2, 260	*6.87	June 16	0200	1760	6.51

Minimum daily discharge, 23 ft3/s, Feb. 13, 14.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1992 TO SEPTEMBER 1993 DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	35	51	e43	e30	e29	e26	50	125	1490	755	219	77
2	35	52	e43	e30	e28	e27	55	139	1360	750	203	74
3	36	45	e40	e28	e28	e28	50	183	1150	775	189	70
4	38	47	e37	e25	e26	e29	54	276	827	632	188	71
5	37	52	e39	e30	e24	e30	57	208	766	507	186	75
6	37	50	e39	e33	e25	e32	53	170	727	433	172	73
7	38	49	e42	e35	e26	e34	50	158	590	401	166	68
8	37	49	e45	e33	e26	e35	49	143	527	393	182	57
9	37	42	e45	e31	e27	e35	56	132	469	380	175	55
10	35	38	e45	e28	e26	e35	56	161	508	373	163	53
11	35	77	e44	e27	e25	e34	56	247	690	392	181	52
12	34	53	e42	e27	e24	e33	53	344	878	391	160	75
13	34	48	e40	e31	e23	e34	52	456	961	384	142	119
14	34	47	e40	e33	e23	e34	50	618	1090	350	146	121
15	33	47	e40	e33	e24	e34	53	752	1430	322	137	117
16	32	45	e40	e32	e24	e34	54	936	1500	304	130	118
17	33	44	e41	e32	e25	e35	54	1050	1320	281	122	126
18	33	43	e41	e32	e27	37	68	1210	1050	264	116	131
19	34	43	e40	e31	e26	37	59	1360	988	248	117	124
20	34	41	e39	e35	e26	36	55	1430	1160	235	116	102
21	33	40	e38	e32	e26	40	63	1680	1350	228	129	98
22	36	47	e38	e30	e26	37	82	1890	1290	237	114	97
23	38	44	e39	e29	e26	43	99	1470	1160	357	105	95
24	35	e42	e39	e29	e26	49	89	1440	916	488	98	94
25	36	e40	e39	e29	e25	53	82	1530	861	297	93	93
26	41	e40	e42	e28	e24	54	105	1860	915	373	100	84
27	39	e42	e44	e27	e24	55	127	1860	952	339	92	61
28	53	e42	e38	e27	e25	55	138	1640	970	265	89	59
29	53	e38	e39	e27	—	51	150	1510	936	239	83	58
30	54	e39	e39	e27	—	49	142	1460	845	247	80	57
31	56	—	e36	e28	—	46	—	1460	—	231	79	—
TOTAL	1175	1377	1256	929	714	1191	2161	27898	29676	11871	4272	2554
MEAN	37.9	45.9	40.5	30.0	25.5	38.4	72.0	900	989	383	138	85.1
MAX	56	77	45	35	29	55	150	1890	1500	775	219	131
MIN	32	38	36	25	23	26	49	125	469	228	79	52
AC-FT	2330	2730	2490	1840	1420	2360	4290	55340	58860	23550	8470	5070

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1943-1993, BY WATER YEAR (WY)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
MEAN	62.2	54.0	46.5	41.6	40.0	43.0	112	597	862	294	94.0	72.1
MAX	208	106	94:9	72.4	64.3	69.0	316	1044	1990	933	244	229
(WY)	1983	1984	1984	1984	1984	1986	1946	1984	1986	1975	1965	1983
MIN	30.8	32.5	27.7	29.6	25.3	26.0	37.2	162	204	67.4	37.5	23.9
(WY)	1959	1955	1960	1991	1964	1964	1944	1977	1992	1961	1954	1956

SUMMARY STATISTICS	FOR 1992 CALENDAR YEAR		FOR 1993 WATER YEAR		WATER YEARS 1943-1993	
ANNUAL TOTAL	40413		85074			
ANNUAL MEAN	110		233		193	
HIGHEST ANNUAL MEAN					335	1986
LOWEST ANNUAL MEAN					81.5	1977
HIGHEST DAILY MEAN	882	May 20	1890	May 22	2680	Jun 4 1986
LOWEST DAILY MEAN	27	Feb 20	23	Feb 13	18	Jan 3 1960
ANNUAL SEVEN DAY MINIMUM	31	Feb 16	24	Feb 11	21	Dec 28 1959
ANNUAL RUNOFF (AC-FT)	80160		168700		140100	
10 PERCENT EXCEEDS	318		868		610	
50 PERCENT EXCEEDS	47		53		58	
90 PERCENT EXCEEDS	35		28		33	

e Estimated

Figure 1. Standard water supply paper.

The water supply papers contain the mean daily flows and the total volume of flow for the various gage streams in the state. The station history is usually listed before the monthly data. The station history contains the number of years of record that the station has, whether or not water is withdrawn above the gaging station, the maximum and minimum flows recorded at the gaging site, and the date at which these flows occurred.

The U.S. Geological Survey (USGS) has also compiled the data from its water supply papers into a computer data bank called WATSTORE. WATSTORE can be accessed through most computer terminals using passwords and data provided by USGS. Most NRCS state offices have accounts with USGS to access their WATSTORE data. A variety of data can be accessed and analyzed through this computer system. Examples are: mean daily flows, peak flow data, both high and low flow durations, historical events, and monthly and annual statistics. WATSTORE also has the capability of doing statistical analyses on the entire historical data series of a station or on a data series.

Other federal agencies also compile streamflow data on streams of interest. The U.S. Army Corps of Engineers generally maintains streamflow data on larger streams than are of interest to NRCS. The USDA Forest Service maintains streamflow data on study watersheds. The USDA Agricultural Research Service also maintains streamflow data.

The U.S. Department of Interior, through the Bureau of Reclamation, monitors streamflow within irrigation projects. These data are available by contacting the local Bureau of Reclamation office within the irrigated areas. In some states, the state engineer will do streamflow measurements through the Department of Ecology or other state agencies responsible for monitoring streamflow. Some irrigation companies also maintain stream records on small side streams. In addition, county resource agencies and private power companies may compile this data.

Activity 1

At this time, complete activity 1 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Activity 1

1. List the three general needs for streamflow data.

   a. ____

   ____

   b. ____

   ____

   c. ____

   ____

2. Name at least five sources of streamflow data.

   a. ____

   b. ____

   c. ____

   d. ____

   e. ____

Streamflow Variability

Streamflow varies from year to year and from season to season due to the amount of precipitation received in the upper watershed. Streamflow is a part of the hydrologic cycle. It is the one area where water is in a confined channel and can be measured. Storm patterns and the type of precipitation event also cause a variation in the daily rates of streamflow throughout the year.

In many of the streams in the northern part of the United States, snowmelt makes up the major portion of the annual flow. Streamflow will be lowest in late summer and early fall months and will gradually reach a peak flow in early spring when snowmelt is at a maximum.

Streamflow in the southern part of the United States is affected more by annual rains. Streamflow variations below large irrigation reservoirs of power dams are man-made and are based on the need for irrigation water downstream or the power requirements of the power company's customers.

Accuracy of Measurement

The accuracy of discharge data depends primarily on:

- the stability of the stage-discharge relation or the stability of the stream bed
- the accuracy of observations of stage, measurements of discharge, and interpretation of records.

The station description (fig. 1) under "Remarks" generally states the degree of accuracy of the records. "Excellent" means that about 95 percent of the daily discharges are within 5 percent, "good" within 10 percent, and "fair" within 15 percent. "Poor" means that daily discharges have less than "fair" accuracy.

Key point

Figures of daily mean discharge are shown to the nearest hundredth of a cubic foot per second for discharges of less than 1 cfs, to tenths between 1.0 and 10 cfs, to whole numbers between 10 and 1,000 cfs, and to three significant figures greater than 1,000 cfs. The number of significant figures used is based solely on the magnitude of the figure listed for partial-record stations and miscellaneous sites.

Discharge at many stations, as indicated by the monthly mean, may not reflect natural runoff due to the effects of diversion, consumptive use, regulation, evaporation, or other factors. For such stations, discharge in cubic feet per second per square mile and runoff in inches are not published unless satisfactory adjustments can be made for such effects. Evaporation from a reservoir is not included in the adjustments for changes in reservoir contents, unless it is so stated. Even at those stations where adjustments are made, large errors in computed runoff may occur if adjustments or unadjusted losses (consumptive use, evaporation, seepage, etc.) are large in comparison with the observed discharge.

Uncertainty in Data Acquisition

The total uncertainty or error inherent in hydrologic data and information is generally very complex and difficult to assess. Direct-reading scalar values, such as stream stage, channel width, or stream depth, present little chance for error, thus the uncertainty is small. Stream discharge, on the other hand, is more complex, because the discharge determination is made using a combination of scalar and vector quantities, each having inherent errors that are additive (algebraically) in evaluating the total uncertainty.

Much of the uncertainty associated with acquisition of water data and information can be eliminated through the use of standard recommended methods. Because almost all errors (both random and systematic) are due to either the observer, the instrument or equipment, or the measurement method, the total uncertainty can be decreased appreciably through standardization, familiarity, confidence, and the use of recommended methods for data acquisition.

By decreasing the random and systematic error, and therefore, the total error, the accuracy and precision of the data are increased, and the reliability of the data and information is increased.

Water Rights

The two basic divergent doctrines regarding the right to use water in the United States are riparian and appropriation. In different states they are recognized either separately or as a combination of both doctrines. They apply only to surface water in natural water courses and to water in well defined underground streams.

The riparian doctrine comes to us from English common law based on the principle that it is the right of a riparian owner to make reasonable use of the stream's flow, provided the water is used on riparian land. Riparian land is described as land that is contiguous (joins or touches) to a stream or body of surface water. Land ownership includes the right to access and use the water, and this right is not lost by nonuse. Reasonable water use generally implies that the landowner may use all that is needed for drinking, household, and livestock use. Where large herds of livestock are watered or where water is used for irrigation, the riparian owner is not permitted to exhaust the remainder of the stream.

The doctrine of prior appropriation is based on the priority of development and use. In other words, the first to develop and put the water to beneficial use has a prior right to continue its use. The right of appropriation is acquired by filing a claim in accordance with the laws of the state in which the use is proposed. According to the doctrine of prior appropriation, the water must be put to a beneficial use, but the appropriator has the right to all water required for that use in a given time and place. This principle assumes that it is better to let individuals with prior claims take all the water, rather than to distribute inadequate amounts to several owners.

Figure 3. The curve number Aligner with a plotted example.

Appropriated water rights are not limited to riparian land and may be lost by nonuse or abandonment. The doctrine of prior appropriation is recognized in all 17 western states, although some states use a combination of it and the riparian doctrine.

State Agencies

Different states have different agencies that are responsible for water rights, so there is no one agency to look for. Some possible agencies are the State Department of Water Resources, the State Department of Ecology, and the State Department of Natural Resources. In some cases, no state agency is responsible for water rights. In a few cases, NRCS state engineers have the responsibility for the water rights.

Activity 2

At this time, complete Activity 2 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Activity 2

1. What are three general causes of streamflow variability?

   a. ____

   ____

   b. ____

   ____

   c. ____

   ____

2. What are the two basic doctrines of water rights?

   a. ____

   b. ____

3. What is the difference between the two water rights doctrines?

a. ____

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b. ____

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c. ____

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4. Discuss problems associated with listing the state agencies responsible for water rights.

After comparing your answers with the solution, continue with the audiovisual presentation.

Summary

You should now be able to identify the sources and uses of streamflow data, to describe the two water rights doctrines, and to identify common state agencies responsible for water rights.

Retain this Study Guide as a reference until you are satisfied that you have successfully mastered the material. It will provide an easy review at any time if you should encounter a problem.

If you have had problems understanding the module or if you would like to take additional, related modules, contact your supervisor.

When you are satisfied that you have completed this module, remove the Certification of Completion sheet (last page of the Study Guide), fill it out, and give it to your supervisor to submit, through channels, to your Training Officer.

Activity Solutions

Activity 1

1. List the three general needs for stream flow data.

   a. *Water forecasting by the Water Supply Forecasting staff at the West National Technical Center.*

   b. *Water rights for irrigation and municipal use, and the design and operation of irrigation systems, water supply, and recreation reservoirs.*

   c. *Design of water resource projects, such as rock riprap and stream channel improvement jobs, by NRCS engineers.*

2. Name at least five sources of streamflow data.

   a. *U.S. Geological Survey*

   b. *U.S. Army Corps of Engineers*

   c. *USDA Forest Service*

   d. *USDA Agricultural Research Service*

   e. *U.S. Department of Interior, Bureau of Reclamation*

   f. *State agencies*

   g. *Private companies*

Activity 2

1. What are the three general causes of streamflow variability?

    a. *Storm patterns and types of precipitation from annual rains*

    b. *Snowmelt*

    c. *Location below large irrigation or power reservoirs*

2. What are the two basic doctrines of water rights?

    a. *Riparian*

    b. *Appropriation*

3. What is the difference between the two water rights doctrines?

    a. *Riparian water rights apply only to land adjoining a stream or body of surface water; appropriation rights do not.*

    b. *Riparian water rights are maintained even if not used; appropriation water rights are lost by nonuse.*

    c. *Where riparian water rights are concerned, everyone along the stream has an equal right to a certain amount of water. Where appropriation water rights are concerned, the appropriator has the right to all water required by a beneficial use at a given time and place, even if others do not get any. This is based on the idea that the first to develop and put water to beneficial use has a right to continue its use.*

4. Discuss problems associated with listing the state agencies responsible for water rights.

   Generally, no common state agency is responsible for water rights. Each state has its own guidelines and agency that is responsible. Some states do not have any agency that has water rights responsibility. In a few cases, the state engineer has the responsibility.

Appendix A

Video Narrative

This appendix includes the complete script of the video presentation used in conjunction with the Study Guide text.

Streamflow Script

This module provides a basic introduction to streamflow as it pertains to the Natural Resources Conservation Service.

Upon completion of this module, you will be able to:

- Identify Natural Resources Conservation Service needs for streamflow data.
- List the various sources where the NRCS can obtain streamflow data.
- Describe streamflow variability.
- Distinguish between riparian and appropriation water rights, and, last,
- Identify the state agencies responsible for water laws.

Now, let's discuss why the NRCS needs streamflow data.

The National Water and Climate Center in Portland, Oregon uses streamflow data in many of its forecasting procedures.

Water rights for irrigation and municipal use are heavily dependent on streamflow data.

The design and operation of many irrigation systems in the western states are dependent on knowing how much water is flowing in a particular stream.

Natural Resources Conservation Service engineers need to have streamflow data when designing rock riprap and stream channel improvement jobs.

In review, there are three general needs for streamflow data in the NRCS:

- water supply forecasting by the National Water and Climate Center in Portland, Oregon
- irrigation design scheduling and operation in the western states
- water resource project planning and design.

The next topic for discussion is Sources of Streamflow Data.

Sources of streamflow data include the U.S. Geological Survey, U.S. Army Corps of Engineers, USDA's Forest Service and Agricultural Research Service, the Department of Interior's Bureau of Reclamation, and private companies.

At this time, press "Pause" or "Stop" on your tape player and turn to Activity 1 in the Study Guide. You will be asked to review the topics "Needs for Streamflow Data" and "Sources of Streamflow Data" and to complete the activity. When you have finished Activity 1, continue with the audiovisual presentation.

The next topic is streamflow variability. Streamflow varies from year to year and from season to season because of the amount of precipitation received in the upper watershed.

Storm patterns and types of precipitation can cause a variation in the daily rate of streamflow throughout the year.

In many of the streams in the northern states, snowmelt makes up a major portion of the annual flow.

Streamflow will be the lowest in the late summer and early fall months and will gradually reach a peak flow in the early spring when snowmelt is at a maximum.

Streamflow in the southern part of the United States is affected more by annual rains.

Finally, streamflow variations below a large irrigation reservoir or power dam are manmade and based upon the need for irrigation water downstream or power company requirements to meet customer needs.

In review, streamflow variability is generally caused by:

- the amount of precipitation
- the type of precipitation; that is rainfall, snowfall
- man-made regulation.

Water rights, our next topic, are principally of two types: riparian and appropriation.

Riparian water rights apply only to land adjoining a stream, cannot be lost by nonuse, and imply an equal sharing by all land users along the stream.

Lands under appropriated water rights do not need to adjoin a stream, may be lost by nonuse, and vary from user to user based on a first come first served basis and plant need interpretation.

The last topic to be covered in this module is the identification of common state agencies responsible for water rights.

There is no one state agency responsible for water rights. Rather, there are almost as many different agency names as there are states. In fact, some states do not have any agency assigned water responsibility. In a few cases, state engineers have the responsibility for water rights.

At this time, press "Pause" or "Stop" on your tape player and complete Activity 2 in the Study Guide. You will have a brief reading assignment before you complete each activity. When you have completed both activities, continue with the audiovisual presentation.

In summary of this module, streamflow data is needed for water forecasting, irrigation design and operation in western states, and water resource project planning and design.

Sources of streamflow data include the U.S. Geological Survey, U.S. Army Corps of Engineers, USDA's Forest Service and Agricultural Research Service, the Department of Interior's Bureau of Reclamation, and private companies.

The general causes of streamflow variabilities are amounts of precipitation and types of precipitation, such as annual rains, snowmelt and man-made regulation.

There are two major types of water rights—riparian and appropriation. Riparian rights apply only to lands adjoining a stream, appropriation rights do not. Riparian rights are maintained; appropriation rights are lost by nonuse.

Riparian rights allow everyone along a stream to share equally. Appropriation rights use a "first come first served basis" philosophy. Appropriated water rights do not need to adjoin a stream.

The only way to determine which state agency is responsible for water rights in your state is to ask. There is no one definite regulatory agency for each state. In fact, some states do not have water rights regulation at all.

This concludes the Streamflow Module. If you have questions your Study Guide does not answer, ask your supervisor for help.

Hydrology Training Series
Module 115—Streamflow

Certificate of Completion

This is to certify that

____

has completed Hydrology Training Series
Module 115—Streamflow
on ________________ and should be credited with three hours of training.

Signed _________________________ _________________________
Supervisor/Trainer Participant

Completion of Hydrology Training Series
Module 115—Streamflow
is acknowledged and documented in the above-named employee's record.

Signed _________________________ Date ________________
Training Officer

United States Department of Agriculture, Natural Resources Conservation Service